IOP Conf. Series: Materials Science and Engineering **400** (2018) 032010 doi:10.1088/1757-899X/400/3/032010

The alternative manufacturing process of the mechanism housing. A PDCPD based housing of the power steering system

M Sobek, A Baier and L Grabowski
Silesian University of Technology, Gliwice, Poland, The Faculty Of Mechanical Engineering, Institute Of Engineering Processes Automation And Integrated Manufacturing Systems

E-mail: michal.sobek@polsl.pl

Abstract. The automotive industry is one of the largest branches of the market. Directly behind the armaments and aircraft industries is the most dynamically developing area of searching for new engineering solutions. The search direction is usually related to the need and needs to meet increasingly high safety requirements and growing customer requirements. The task of searching for a new engineering solution seems to be even more difficult considering the assumptions that the new solution will meet. These are not only assumptions related to the nature of the product itself. A very important role in the whole process is covered by the financial aspect of the entire undertaking. Many elements of motor vehicles are very intricately designed nowadays. It is directly related to the increasing care for the user's safety. For a product to be competitive on the market, however, it must still have the right price. Therefore, new solutions for the market must be characterized by an appropriate price/quality ratio. This assumption guided designers when designing new solutions. The automotive industry is very demanding. The production of parts for the needs of this branch of the market involves the fulfilment of very high requirements regarding the class of components performance. This allows ensuring the good cooperation of components in very difficult conditions that accompany the work of the vehicle. Usually, to achieve the appropriate accuracy class, for example, a surface processing should be used. In the case of car parts, in the production process of which machining is involved, a significant increase in the product price should be expected. The machining process, despite very sophisticated and advanced technologies, is still relatively time-consuming. The additional time allocated to this process translates directly into the cost of the target product. In the paper titled " The alternative manufacturing process of the mechanisms housing. A PDCPD based housing of the power steering system" the process of an alternative method of manufacturing the housing of mechanical systems on the example of the power steering housing was described. The developed system eliminates the machining process. During the carried-out research, the main focus was on developing the casting technology of the gear housing using a two-component composite material. Also, the paper describes specially designed and constructed test stand for casting the body and the process of preparation of individual components previously made from PDCPD material.

1. Introduction

There are many well developing industries in the market. I can be easily noticed that one of the best developing branches of industry is an automotive industry. Such a situation is caused by increasing

demand for motor vehicles in recent years. Non-stopping raise of safety rules in production process is a direct reason for searching new solutions. Complex research part makes the whole production process of a target product much more expensive. Since the target customer can not be burdened with the entire costs associated with the research process of a new solution, these costs should be hidden or minimized by reducing the costs of operations during the production process of the target product. The cost reduction can also take place by replacing the material from which the product is made. Metal can be replaced with a much cheaper composite material whose mechanical properties do not have to differ from the previously used metal material. However large part of the costs is, absorbed by the very production process of the part whole assembly of parts [1,3,4].

The production process can be optimized in many ways. Starting from minimizing downtimes that generate losses to excluding unnecessary operations from the entire process. In the case of production of a set of parts containing metal components, a large part of the total cost are expenses related to metalworking. This process in most cases involves machining, which involves the use of CNC machines and expensive tools. Despite very advanced tool technology, the cutters and turning tools are subject to wear and, as a result, can be destroyed. The conversion of the machine causes a downtime in the production process which is related unambiguously with generating losses for the entrepreneur. The machining process itself is also a time-consuming process. The necessity of its

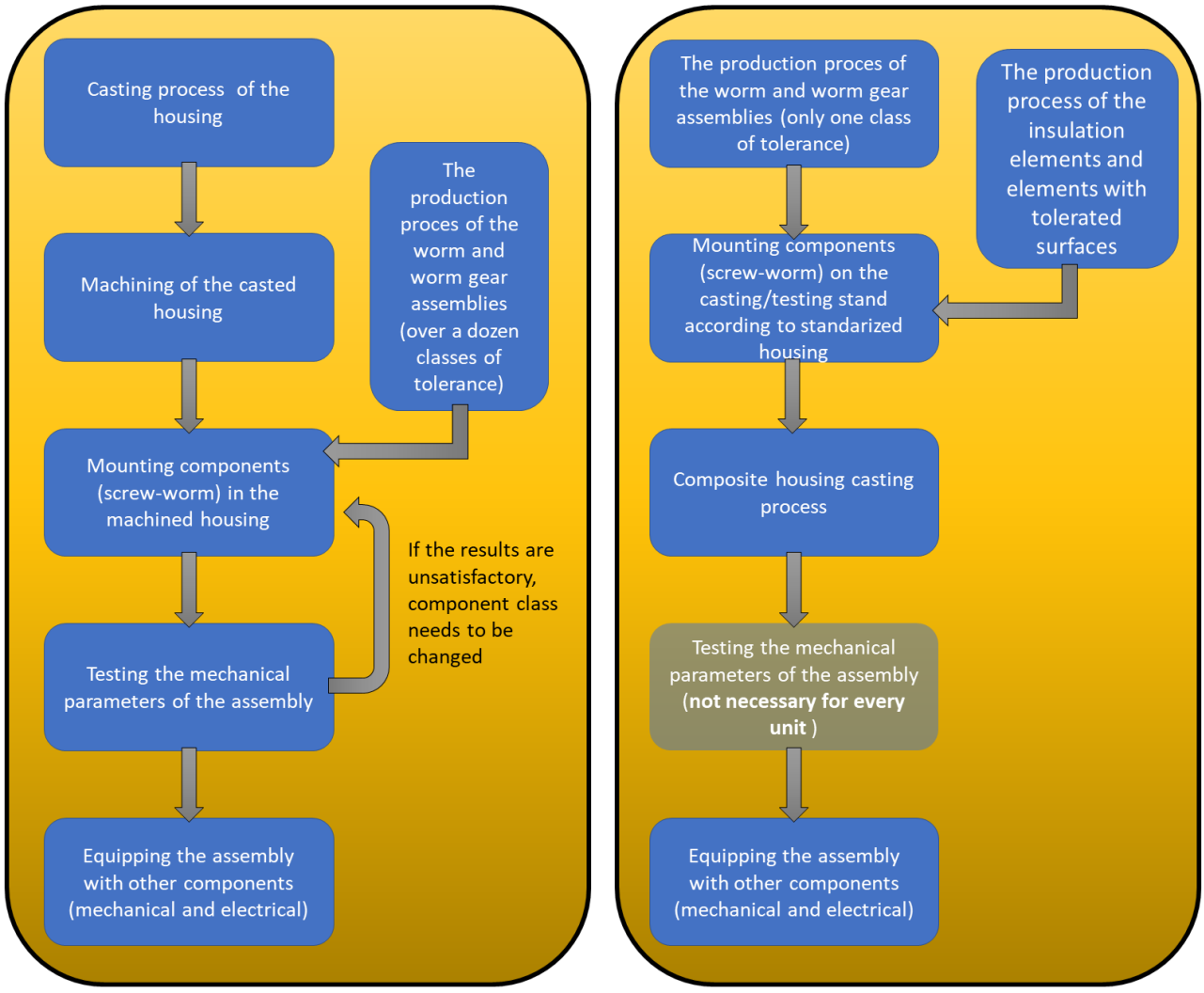

Figure 1. Stages of the power steering housing production - conventional (left) and alternative (right).

implementation is forced to obtain a specific accuracy of the machined surfaces. Usually, these are surfaces that work with other components of the parts assembly [2,4,5,6].

In this paper, the production process of the composite worm gear housing of the power steering system is described. This process is different from the current approach to the production of this class of components. It omits the necessity of using machining at the same time, without reducing the accuracy of the surfaces cooperating with other components of the whole assembly. In the case of the production of the parts of the power steering system, the production process consists of many steps. The conventional production process of the power steering system began with the production of key components of the worm gear – worm and a worm wheel (Figure 1). It is the matching of these two elements that determines the quality of work of the power steering system. Due to the complex geometric form of both elements, they are made in several dozen accuracy classes. At the same time, a cast of the power steering housing made. The cast is made of aluminium, which allows for quite good machining. Each cast is machined in places where the bearing seats will be located, and additional power steering gear instrumentation components such as electronics, electric motor or additional shields will be attached. The machined housing is then equipped with a set of components such as bearings and a pair of worm and worm wheel components. Such prepared set of components is transferred to the test stand, where its mechanical parameters are examined. In the case of receiving results falling within the norms, such a set is equipped with the rest of mechanical and electronic elements. However, when the results are not satisfactory it is necessary to choose elements from another class of accuracy and repeat the test process once more. This process is an iterative process and continues until the appropriate measurement results of the mechanical parameters of the transmission are obtained [5,7,8,9].

Such a process is quite an inconvenient process due to the number of necessary part classes and its iterative nature. All this contributes to the extension of the duration of the process and, as a result, to increased financial outlays. In the case of the alternative production process of the power steering transmission system, it is possible to reduce certain steps due to a completely different approach to the problem (figure 1). The alternative production process of the power steering housing starts with the assembly of the standardized housing on the test bench, which in later steps will also be a manufacturing station. By mounting the reference housing, the geometry of the power steering axle cooperating with each other is determined. Next, the components of the target power steering system together with additional insulating elements are assembled [9,10]. The assembly thus prepared is then covered with an injection mold and poured with a composite material. After the casting process, it is possible to examine the correctness of the components. The research methodology was developed for the needs of the research, and for that purpose the research stand was designed and made. Due to the confidential nature of the conducted research, some descriptions of elements and diagrams had to be replaced by substitute elements.

2. Laboratory research part

Laboratory work began with the preparation of elements necessary for construction of the power steering gear. These elements can be divided into two basic groups:

- Mechanical components that were provided directly by the manufacturer;
- Insulation elements and elements with tolerable surfaces.

Initially, elements such as the worm and worm wheel bushing were made out of a solid polymer cylinder by machining. However, these were attempts to confirm the legitimacy of further proceedings in this direction. After confirming the rightness of the process, it was decided to go a step further.

The worm bushing was cast from the PDCPD composite material (figure 2). For this purpose, a form was used, the core of which was made in such a way as to guarantee the dimensions complying with the principle of assembly of the bearing. The outer surface of the core in two places corresponded to the surface being the bearing seats in the sleeve. Adjusting the process accordingly, it was possible to fit the bearings in the sleeve properly. The same technological process was used in the production of

the worm wheel bushings. In this case, the bushing made of polymer with machining was also used first.

Figure 2. Worm sleeve casted in PDCPD class material.

The same technological process was used in the production of the worm wheel bushings. In this case, the bushing made of polymer with machining was also used first. Next, the target sleeve was made by injecting PDCPD material into aluminum molds (figure 3).

Figure 3. The worm bushing is cast in PDCPD class material with visible sockets under the bearing.

At the same time, a reference housing, for which the values of mechanical parameters were known, was mounted on the test stand (figure 4) equipped with four movable supports.

Precise mounting of the reference housing was possible due to movable supports, two of which are able to perform a translational movement along the axis of the worm and two movements of the translation in accordance with the axis of the worm wheel and in the perpendicular direction, vertical to this axis. Determining the positions of supports defines the distances between the screw and worm axis relative to each other. After the dismounting of the reference housing, the insulating elements and

bushings equipped with gear components (worm, worm wheel, bearings) are installed in its place (figure 5).

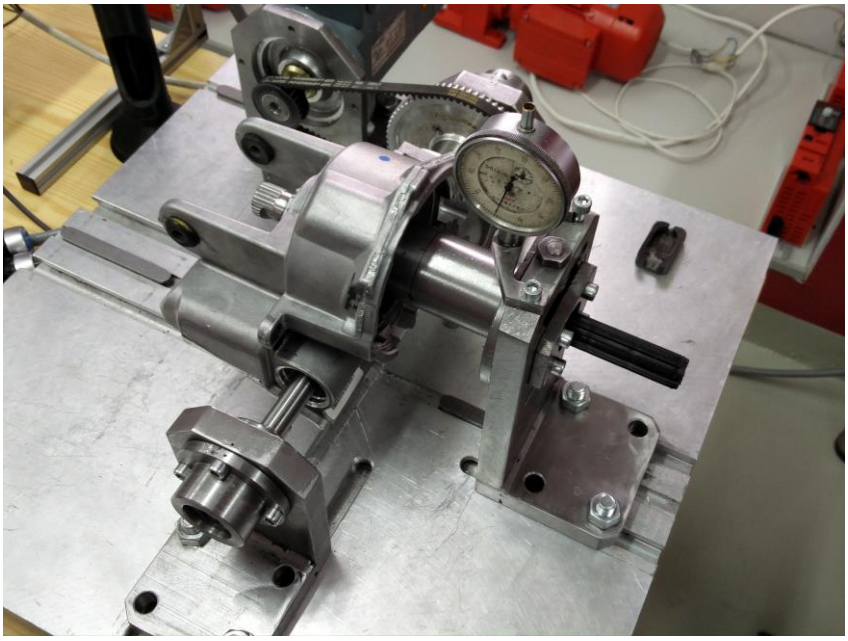

Figure 4. Test/production bench of power steering housing with the reference body mounted.

Determining the positions of supports defines the distances between the screw and worm axis relative to each other. After the dismounting of the reference housing, the insulating elements and bushings equipped with gear components (worm, worm wheel, bearings) are installed in its place (figure 5).

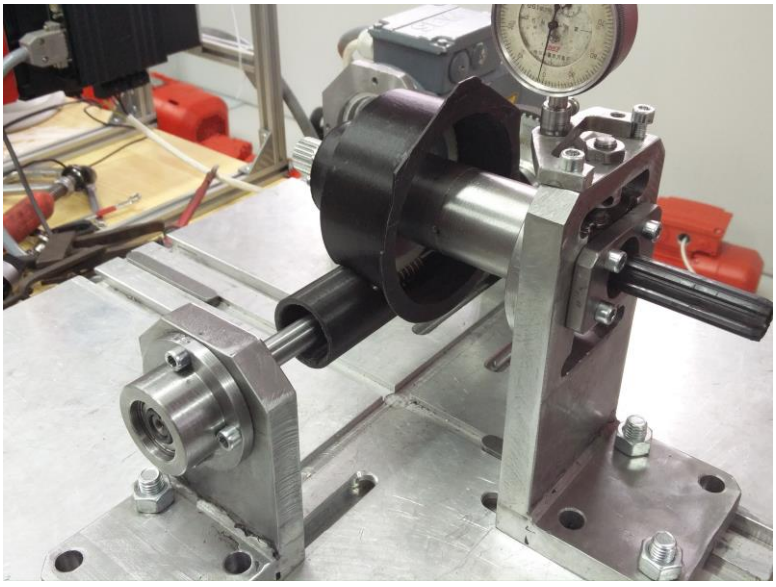

Figure 5. Test/production bench of power steering gear housing with mechanical and insulating parts mounted.

Insulation elements are designed to prevent the liquid composite from entering the working space of the transmission components. The insulating elements in relation to the screw and worm bush are additionally sealed at this stage by means of a special glue that allows to connect the PDCPD class material and the polymer from which the goblets were made. In this way, the prepared components had to be covered with elements of the aluminum body mold. Each part of the mold relative to the other part of the mold had to be sealed with a special silicone that did not react with the PDCPD class material. It was also necessary to seal the places where the components of the housing, i.e. the worm and worm wheel goblets, were in contact with the injection mold. This was to guarantee the tightness of the entire mold and not allow the composite material to leak beyond the volume of the mold. During the injection process about 500ml of PDCPD material was used. It was injected through a hole located at the base of the mold. The material was pressed in using a special dispenser and mixed with the help of the mixing tip. After injecting the appropriate amount of material into the volume of the mold, it was necessary to ensure the correct course of the metathesis reaction, in which two liquid components of the composite will be turn into a monolithic target material. The liquid form must be heated to initiate the metathesis reaction. The characteristic of the metathesis reaction is self-driving. Depending on the size of the volume, this reaction may take place in various ways. In the case of a large volume, this reaction is quite turbulent, therefore, as a result, a lot of heat is released which further accelerates it. In this case, the reaction temperature can reach up to 250 ℃. Casting small volumes will require initiating the reaction by heating the mold or material directly. The transmission housing is mostly a solid with thin walls, and there is also a need to initiate a reaction. After cooling the mold, the housing is suitable for pulling out and optional testing of mechanical parameters [10-12].

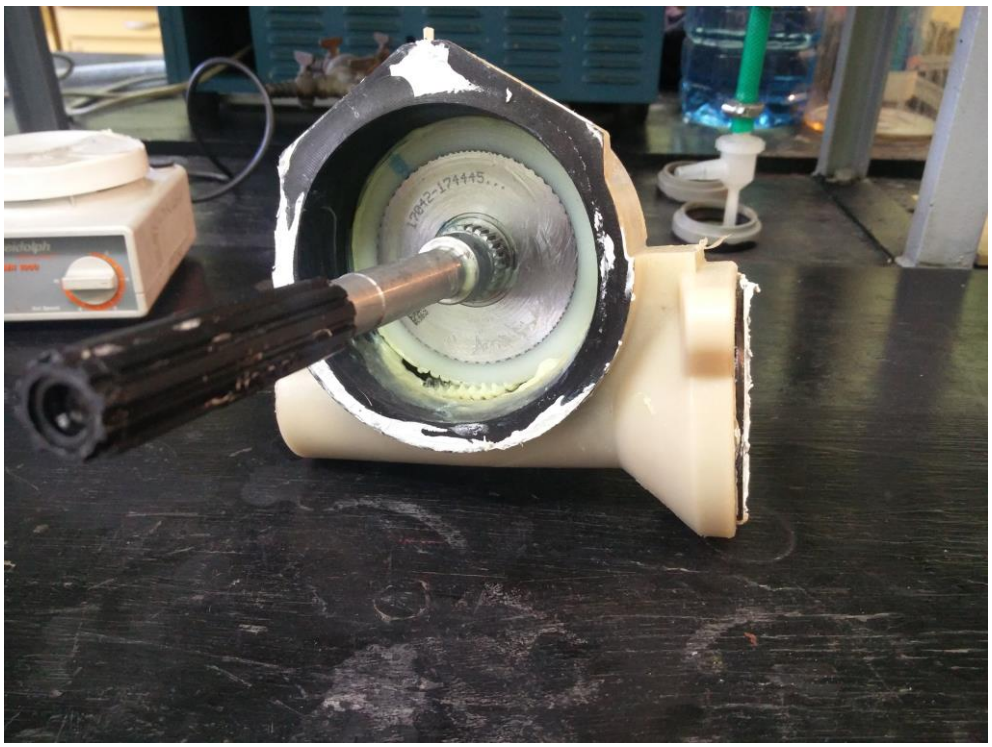

Figure 6. Housing made using an alternative production method [5].

3. Results and conclusions

During the laboratory tests, the research team obtained several copies of functional bodies. The mechanical parameters of the manufactured bodies differ from those assumed before the manufacturing process as well as from those obtained in the process of testing the standard body. The process of casting pre-set transmission components is a process that allows to resign from machining

processes during the production of the power steering gear housing. Having a reference housing system at its disposal, the correct operation of which was examined in the preliminary testing process, it is possible to observe the distance between the axes by observing torque changes so that the torque value is the same as in the case of the reference system.

After analysing all the results and conclusions drawn from the observations during the test, it can be clearly stated that it is possible to manufacture the power steering gear housing using an alternative production method. Further work will focus on refining the methodology and reducing transmission resistance after casting.

4. References

[1] Herbuś K and Ociepka P 2016 *IOP Conf. Series: Materials Science and Engineering* **145** 042018
[2] Herbuś K. and Ociepka P 2016 *IOP Conf. Series: Materials Science and Engineering* **145** 052010
[3] Ociepka P and Herbuś K 2015 *IOP Conf. Series: Materials Science and Engineering* **95** 012101
[4] Baier A, M Majzner, Sobek M, Grabowski Ł 2016 *IOP Conf. Series: Materials Science and Engineering* **145**(2) 022023
[5] Baier A, Sobek M, Grabowski Ł *IOP Conf. Series: Materials Science and Engineering* **301** 1757-8981
[6] Baier A, M. Brajza, M. Erm, Grabowski Ł, P. Papaj and Sobek M 2013 Advanced analysis of the Greenpower race car, *Intern. J. of Materials & Product Technology*
[7] Baier A, Baier M, Dusik D, Sobek M, Papaj P and Grabowski Ł 2014 Computer aided Process of designing the mechatronic Silesian Greenpower electric car, *Advanced Materials Research* **1036** 674
[8] Baier A, Baier M, Dusik D, Grabowski Ł, Miera A and Sobek M 2013 Computer aided Process of designing the mechatronic Silesian Greenpower electric car, *Selected Engineering Problems* **4**
[9] Buchacz A, Baier A, Herbuś K, Ociepka P, Grabowski Ł and Sobek M 2018 *Maintenance and Reliability* **20**(1) 137
[10] Baier A, Sobek M and Grabowski Ł 2016 *IOP Conf. Series: Materials Science and Engineering* **301**1757-8981
[11] Baier A, Sobek M and Grabowski Ł 2017 Car's power steering and worm gear test stand *ModTech 2017, Book of abstracts* (*June 14-17, 2017, Sibiu, Romania)* (Iasi: ModTech Publishing House)
[12] Baier A, Sobek M and Grabowski Ł 2017 Molding of strength testing samples using modern PDCPD material for purpose of automotive industry *ModTech 2017, Book of abstracts* (*June 14-17, 2017, Sibiu, Romania)* (Iasi: ModTech Publishing House)